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THE EFFECT OF VARIOUS FORMS OF SULPHUR AND NITROGEN ON CALCIUM AND MAGNESIUM CONTENT AND UPTAKE IN SPRING WHEAT (*TRITICUM AESTIVUM* L.) AND COCKSFOOT (*DACTYLIS GLOMERATA* L.)

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Abstract

The study assessed the effect of various forms of sulphur ($Na_2S_2O_3$, elemental S and Na_2SO_4) and nitrogen (UAN-30, NH_4NO_3) on calcium and magnesium content and uptake in spring wheat and cocksfoot. A two-year pot experiment was conducted on soil material of clayey silt granulometric composition. Before the experiment, the soil was characterized by slight acidity and low content of assimilable forms of phosphorus, potassium, magnesium and sulphur. The results show that the experimental factors caused noticeable variation in the content and uptake of calcium and magnesium in spring wheat and cocksfoot. Among the sulphur fertilizers, the greatest increase in calcium and magnesium content and uptake was produced by application of sodium sulphate. The increase in calcium and magnesium uptake was more marked in the case of plants fertilized with nitrogen in the form of ammonium nitrate. The effect of nitrogen fertilization on the analyzed parameters also depended on the species of plant. Wheat grown in the series with ammonium nitrate was characterized by higher Ca and Mg content and uptake than plants fertilized with nitrogen in the form of liquid UAN 30. Calcium uptake by wheat fertilized with NH_4NO_3 was on average 15% higher for grain and 9% higher for straw compared to wheat fertilized with UAN 30. As for magnesium, the increase was 24.5% and 18%, respectively. Concerning cocksfoot, fertilization with UAN 30 had a greater affect on content and uptake of the analyzed nutrients than ammonium nitrate.

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Key words: calcium content, magnesium content, uptake, form of sulphur, nitrogen fertilization, spring wheat, cocksfoot.

WPŁYW RÓŻNYCH FORM SIARKI I AZOTU NA ZAWARTOŚĆ ORAZ POBRANIE WAPNIA I MAGNEZU PRZEZ PSZENICĘ JARĄ *(TRITICUM AESTIVUM* L.*)* I KUPKÓWKĘ POSPOLITĄ (*DACTYLIS GLOMERATA* L.*)*

Abstrakt

W pracy oceniono wpływ różnych form siarki ($Na_2S_2O_3$, S el. i Na_2SO_4) i azotu (RSM-30, NH_4NO_3) na zawartość i pobranie wapnia i magnezu przez pszenicę jarą i kupkówkę pospolitą. Dwuletnie doświadczenie wazonowe przeprowadzono na materiale glebowym o składzie granulometrycznym pyłu ilastego. Gleba przed doświadczeniem charakteryzowała się lekko kwaśnym odczynem oraz niską zawartością przyswajalnych form fosforu, potasu, magnezu i siarki. Wykazano, że czynniki doświadczalne widocznie zróżnicowały zawartość i pobranie wapnia i magnezu przez pszenicę jarą i kupkówkę pospolitą. Spośród nawozów siarkowych największy wzrost zawartości i pobrania wapnia oraz magnezu przez rośliny spowodowało zastosowanie siarczanu sodu. Wzrost pobrania wapnia i magnezu był bardziej wyraźny w przypadku roślin nawożonych azotem w postaci saletry amonowej. Wpływ nawożenia azotem na analizowane parametry był także uzależniony od gatunku uprawianej rośliny. Pszenica uprawiana w serii z saletrą amonową charakteryzowała się wyższą zawartością oraz pobraniem Ca i Mg w porównaniu z wartościami uzyskanymi dla roślin nawożonych azotem w formie płynnego nawozu RSM-30. Pobranie wapnia przez pszenicę w obiektach NH_4NO_3 było średnio o 15% większe w przypadku ziarna i o 9% w przypadku słomy w porównaniu z obiektami nawożonymi RSM-30. W przypadku magnezu wzrost ten wynosił odpowiednio 24,5 i 18%. W przypadku kupkówki, nawożenie RSM-30 w większym stopniu niż saletrą amonową wpływało na zawartość i pobranie analizowanych składników przez rośliny.

Słowa kluczowe: zawartość wapnia, zawartość magnezu, pobranie, forma siarki, nawożenie azotem, pszenica jara, kupkówka pospolita.

INTRODUCTION

Calcium is an essential nutrient for the proper growth and development of plants (ADCOCK et al. 2001). Magnesium is a component of plant tissues serving various physiological functions. Supplying plants with appropriate amounts of these macroelements is essential for the quantity and quality of yields. The literature indicates that fertilization with sulphur affects the uptake and utilization of nutrients by plants, including calcium and magnesium (MCGRATH et al. 1996), while sulphur deficiency can significantly limit their utilization of other nutrients (SEPÚLVEDA et al. 1993, LOŠÁK et al. 2000). At the same time, excess sulphur generally has a negative effect on the chemical composition of plants and acts antagonistically to uptake of certain ions (SKWIERAWSKA et al. 2006b). Appropriate nitrogen fertilization is also necessary for proper plant production. The amount and form of fertilizer

applied are important as well (HOWARD et al. 2002). Hence, the aim of this study was to determine the effect of various forms of sulphur and nitrogen on calcium and magnesium content and uptake in spring wheat and cocksfoot.

MATERIALS AND METHODS

The study was based on plant material obtained in a two-year strict pot experiment conducted on soil material taken from the arable layer of brown soil of clayey silt granulometric composition. The soil was characterized by slight acidity and low content of assimilable forms of phosphorus, potassium, magnesium and sulphur.

The experiment was set up in a completely randomized design. There were two variables: the form of nitrogen fertilizer and the form of sulphur. Nitrogen was applied in the form of UAN 30 (urea ammonium nitrate solution) and NH_4NO_3 (granular form), and three forms of sulphur were used – $Na_2S_2O_3$, elemental S and anhydrous Na_2SO_4. The fertilizers were applied according to the scheme in Table 1. Sulphur in the form of $Na_2S_2O_3$ and Na_2SO_4 was applied in liquid form, and elemental sulphur was added in solid form. Before weighted portions were measured out, the granules were pulverized in an agate mortar.

This paper concerns the effect of the experimental factors on calcium and magnesium content and uptake by spring wheat (*Ismena* variety) and cocksfoot (*Bepro* variety). Nitrogen was applied to plants in the amount of 0.14 g $N \cdot kg^{-1}$ soil, and sulphur in the amount of 0.025 g $S \cdot kg^{-1}$ soil. Half of the nitrogen was applied before sowing, and the remainder after the plants were thinned to an optimal number in a pot. After fully mature wheat (straw and grain) and cocksfoot were harvested, calcium and magnesium content in average samples was determined using atomic absorption spectrometry (Hitachi Z-8200). Uptake of these elements by the plants was calculated based on the content of these nutrients and the yield during the vegetative period.

RESULTS AND DISCUSSION

Calcium and magnesium content and uptake in dry mass of the test plants depended on the experimental factors applied, the species and organ of the plant, and in the case of cocksfoot, on when it was harvested (Table 1).

Calcium content in wheat grain ranged from 0.92 to 1.32 g $Ca \cdot kg^{-1}$. A decrease in calcium content caused by sulphur fertilization was noted

Table 1

The effect of sulphur form and nitrogen fertilization on the calcium and magnesium content in spring wheat and cocksfoot and uptake of these elements

Object	Spring wheat				Cocksfoot			
	grain		straw		first cut		second cut	
	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
Content of calcium and magnesium (g Ca, Mg · kg^{-1})								
RSM-30	1.21	1.02	4.32	0.81	8.51	2.31	7.12	2.29
RSM-30 + $Na_2S_2O_3$	1.10	1.21	4.80	0.81	9.23	2.32	8.53	2.25
RSM-30 + elementary S	1.10	1.04	4.71	1.03	8.94	2.01	7.90	2.20
RSM-30 + Na_2SO_4	1.23	1.42	5.04	1.02	10.23	2.35	9.71	2.31
NH_4NO_3	0.92	1.34	4.43	0.92	8.09	2.28	7.82	2.21
NH_4NO_3 + $Na_2S_2O_3$	1.12	1.42	4.59	0.92	8.53	2.40	8.05	2.35
NH_4NO_3 + elementary S	1.23	1.20	4.68	1.01	8.00	2.41	7.72	2.20
NH_4NO_3 + Na_2SO_4	1.32	1.53	5.12	1.20	9.90	2.61	9.51	2.41
Uptake of calcium and magnesium (g Ca, Mg · pot^{-1})								
RSM-30	0.016	0.014	0.077	0.014	0.105	0.029	0.113	0.036
RSM-30 + $Na_2S_2O_3$	0.018	0.020	0.110	0.019	0.125	0.031	0.158	0.042
RSM-30 + elementary S	0.017	0.016	0.101	0.022	0.115	0.026	0.142	0.039
RSM-30 + Na_2SO_4	0.020	0.023	0.112	0.023	0.145	0.033	0.189	0.045
NH_4NO_3	0.013	0.019	0.082	0.017	0.090	0.025	0.102	0.029
NH_4NO_3 + $Na_2S_2O_3$	0.019	0.024	0.110	0.022	0.103	0.029	0.123	0.036
NH_4NO_3 + elementary S	0.021	0.020	0.109	0.024	0.092	0.028	0.115	0.033
NH_4NO_3 + Na_2SO_4	0.023	0.027	0.126	0.029	0.133	0.035	0.155	0.039

in wheat fertilized with UAN 30 + $Na_2S_2O_3$ and UAN 30 + elemental S, where grain contained 10% less of this nutrient than in objects without sulphur. In the object with UAN 30 and sulphur applied in the form of sodium sulphate, however, no clear change in calcium content was noted in wheat grain. A more marked increase, 33% on average, was observed in the calcium content of spring wheat grain in all of the plants fertilized with ammonium nitrate and sulphur. SKWIERAWSKA et al. (2006b) also noted an increase in calcium content in the grain of cereal crops after application of sulphur in the form of sulphate and elemental S compared with objects without sulphur. Calcium content in wheat straw was higher than in the grain, ranging from 4.32 to 5.12 g $Ca \cdot kg^{-1}$. An increase in Ca content in dry mass of straw was noted in all objects to which sulphur was added, averaging 10.5%, compared with plants which were not fertilized with this nutrient. Calcium content was higher in the dry mass of the first cut of cocksfoot, ranging from 8.00 to 10.23 g $Ca \cdot kg^{-1}$, while in the plants from the second cut it ranged from 7.12 to 9.71 g $Ca \cdot kg^{-1}$. A slight decrease in calcium content in this plant was only observed in the object with NH_4NO_3+ elemental S, both in the first and second cuts. In the remaining objects, calcium content in dry mass of cocksfoot increased when sulphur was added.

In plants from most of the objects to which sulphur was applied, magnesium was higher than in the objects without sulphur. As in the case of calcium, the greatest increase in magnesium content in dry mass of the test plants occurred when sulphur was applied in the form of sodium sulphate. On the other hand, a marked decrease in magnesium content was observed in grain of wheat fertilized with NH_4NO_3 + elemental S and in cocksfoot hay from the first cut in the objects with UAN 30 + elemental S. Lower magnesium content was noted in the second cut of cocksfoot fertilized with elemental S, irrespective of the form of nitrogen applied.

The effect of nitrogen fertilizer on magnesium and calcium content in the test plants did not show a clear tendency. In the case of wheat, in some of the objects application of nitrogen in the form of ammonium nitrate was associated with an increase in calcium content compared with analogous objects in the series with nitrogen applied in the form of UAN 30. However, application of UAN 30 was associated with higher calcium content in the dry mass of the plants, both in grain of wheat that was not fertilized with sulphur and in cocksfoot, compared with the objects fertilized with NH_4NO_3.

Magnesium content in the grain and straw of spring wheat in objects where the nitrogen source was ammonium nitrate was about 15-18% higher than where UAN 30 was used. The dry mass of cocksfoot from most of the objects with nitrogen in the form of NH_4NO_3 also contained more magnesium than in objects with UAN 30. CHERNEY et al. (2004) also observed that nitrogen fertilizer in the form of ammonium nitrate stimulated an increase in magnesium content in plants.

Sulphur fertilization caused a marked increase in calcium and magnesium uptake with the yield of both test plants. The most marked increase in uptake of these nutrients compared to the objects without sulphur was observed where its source was sodium sulphate. It seems likely that the presence of sulphate ions in the soil facilitated uptake of magnesium ions (Brodowska, Kaczor 2005). It should be added that the increase in calcium and magnesium uptake in these objects was more marked in the series in which nitrogen was applied in the form of ammonium nitrate than in the objects fertilized with UAN 30. The results obtained are confirmed by studies by other authors (Skwierawska et al. 2006a, b), who found that fertilization with sulphur increased total magnesium and calcium uptake by plants. The increase in uptake of these nutrients by wheat and cocksfoot is partly due to the effect of sulphur on yield of crop plants (Kaczor, Brodowska 2005, 2009).

The effect of nitrogen application on calcium and magnesium uptake by the test plants was varied, as in the study by Koc and Szymczyk (2001). Regarding wheat (grain and straw), nitrogen in the form of NH_4NO_3 stimulated greater uptake of these elements than UAN 30. Calcium uptake by wheat fertilized with NH_4NO_3 was on average 15% higher in the case of grain and 9% higher in the case of straw, compared to objects fertilized with UAN 30. Concerning magnesium, the increase was 24.5% and 18%, respectively.

The effect of nitrogen fertilization on calcium and magnesium uptake by cocksfoot was the reverse of its effect on spring wheat. The first cut of cocksfoot took up on average 18% more calcium with the yield of plants fertilized with UAN 30 compared with analogous objects fertilized with ammonium nitrate. With respect to the second cut, the difference was 21%. Magnesium uptake by cocksfoot from the series with UAN 30, harvested in the second cut, was on average 18.5% higher than in plants fertilized with ammonium nitrate. Therefore, it can be firmly concluded that in objects fertilized with nitrogen in the form of UAN 30 calcium and magnesium uptake by cocksfoot was higher than in the case of NH_4NO_3. The only exception to this rule was magnesium uptake by plants from the first cut of cocksfoot fertilized with elemental sulphur and Na_2SO_4.

CONCLUSIONS

1. Fertilization with sulphur in the form of Na_2SO_4 caused the most marked increase in calcium and magnesium content in dry mass of the test plants.

2. Ca and Mg content in dry mass of spring wheat was higher in objects with nitrogen supplied in the form of ammonium nitrate, while in the case of cocksfoot, in objects fertilized with UAN 30.

3. Application of sulphur, especially in the form of sodium sulphate, caused an increase in uptake of the analyzed elements by spring wheat (straw and grain) and cocksfoot (both cuts).

4. Ca and Mg uptake by spring wheat was higher in the series fertilized with ammonium nitrate, while uptake by cocksfoot was higher in objects in which nitrogen was supplied in the form of UAN 30.

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